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A mechanical model for giant radiating dike swarms

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The Large Igneous Provinces (LIP) is believed to form as results of plume-lithosphere interaction. A recognizable diagnostic feature of the LIP is a swarm of dikes (100 – 1000 km -long) radiating from a single or several focal regions. The models for formation of these dike swarms are mainly based on Venusian analogues (associated with coronae structures) since on Earth these paleo-structures are presumably less likely to preserve due to erosion and later tectonics.

The existing explanation for the geometry of dikes (in horizontal plane) is based on assumption that in a far-field shear stress the dikes are normal to the least principal stress. A small overpressure related to the lithospheric magma reservoir is also assumed. However, this type of models implies several limitations: 1) the dike emplacement is considered as a purely elastic process, 2) all dikes are assumed to intrude simultaneously (no interaction with neighboring dikes). On the other hand, recent geophysical observations suggest that the dikes that apparently belong to the same magmatic event can intersect and can be affected by each other and local crustal heterogeneity. In this study, we attribute the geometry of dikes to irreversible plastic deformation including the path-dependence. We use finite-element elastoplastic simulations to predict the fracture pattern related to the plume-lithosphere interaction. The rheology is governed by a non-associated Mohr-Coulomb plastic flow law. The accuracy of the numerical results is benchmarked versus 2D plane strain analytical solutions for combined shear and internal pressure loads.

We apply our model to the case of the High Arctic LIP. Here, the location of the dike intrusions is based on the interpretation of magnetic anomalies supported by geological and seismic data in the Barents Sea together with timing constraints using U-Pb isotopic ages. The developed model provides a framework for future high-resolution structural and geochronological studies to infer paleostress regime.